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A TRANSITION-PHASE CALCULATION OF A LARGE, HETEROGENEOUS CORE LMFBR

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The disrupted core (transition-phase) behavior for an early version of the heterogeneous core configuration[1] for the Conceptual Design Study (CDS) reactor has been evaluated for a postulated unprotected transient undercooling accident. As a result of the low sodium void reactivity and high incoherence, the initiating-phase was non-energetic. However, extensive axial blanket blockage formation and low fuel losses during the initiating-phase raised the possibility of transition-phase energetics.

The end-of-equilibrium cycle calculation used SAS3D[2] for the initiating-phase and SIMMER-II[3] for the transition-phase, with SASSIN[4] performing the data transfer between the two codes. A slowly developing initiating-phase (approximately 30 s) was predicted, ending with two subprompt critical bursts which produced a large amount of mobile fuel. Clad blockage was extensive in the upper axial blanket, and the lower axial blanket was blocked in the lead channel when the SAS3D calculation was terminated.

The SIMMER-II calculation extended over a 14 s period. During this period, the structure in the core region was progressively destroyed, with only a few central subassemblies remaining at the end. Over half of the

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fissile inventory was removed from the original core region, with the remainder being a dense mixture of liquid and particulate fuel and steel. The transient progressed through a series of subphases where different physical phenomena dominated:

<u>Subphase 1 - Fuel Slumping/Draining - 0 to 2.5 s</u>. The first subphase was characterized by a continuation of the slumping activity predicted in the initiating phase calculation; a series of four prompt- or near-prompt-critical power bursts occurred. The energy released was sufficient to disrupt nearly all of the remaining fuel in all three driver regions. The molten mixture had a sufficiently high average temperature, approximately 4000 K, to become dispersive, thus terminating this series of recriticalities.

<u>Subphase 2 - 1-D Dynamic Dispersive - 2.5 to 6.0 s</u>. The second subphase was characterized by one dimensional dynamic-dispersive (boilup) beha ior; the preferential production of fuel and steel vapor at the pool center and subsequent condensation at the colder extremities kept the mixture axially dispersed and subcritical. The churning mixture rapidly transferred heat to the driver can walls and caused extensive failures within 2 s. The heat loss rates greatly exceeded the power production during this period -- rapidly quenching the fuel-steel mixture, and resulting in a loss of the supporting vapor pressure. The pool subsequently collapsed, producing a super prompt critical burst that reached a maximum reactivity of \$1.10; however, the peak fuel temperatures did not exceed 4700 K.

<u>Subphase 3 - 2-D Dynamic Dispersive - 6.0 to 9.0 s</u>. The third subphase was characterized by two dimensional dynamic-dispersive (boilup) behavior; vapor produced near the hotter pool center was now able to move radially -- with the driver can walls failed -- allowing the liquid mixture to drain

downward and thus slip by the vapor bubbles. Large fuel losses from the core region occurred due to pressures developed during and after the burst which terminated the previous subphase. Progressive disruption of annular and radial blankets is predicted during this subphase, with enrichment dilution of the pool occurring as a result of intermixing. As a consequence, the reactor remained subcritical.

Subphase 4 - Blowdown - 9.0 to 14.0 s. In the final subphase, the dispersive behavior was suppressed as the addition of cold blanket and structure material quenched the pool. Failure of control rod channels permitted venting of noncondensible gases - sodium vapor and fission gas. The drop in pressure permitted entrained gas in the pool to expand and move to the pool surface. A slow collapse then occurred; however, accumulated fuel losses and enrichment dilution prevented recriticality.

The credibility of SIMMER-II transition-phase calculations has been addressed by several different approaches. The basic SIMMER-II fluid dynamics treatment -- which depends on the conservation of mass, momentum, and energy -- has been tested[5] extensively by comparison to both analytic solutions and experiments. In addition, SIMMER-II's ability to predict static reactivity changes between distorted core geometries has been previously established.[6] The testing of models for rate-controlled processes (mass, momentum, and heat-transfer) can be performed only relative to specific dynamic regimes. Two aspects are addressed here:

(1) The assessment of recriticality potential strongly depends on the fissile inventory remaining within the core at a given time, thus the modeling of plugging and freezing phenomena is fundamental. A series of separate SIMMER-II calculations were performed for comparison to recent experiments.[7] It was determined[8] that the different penetration characteristics observed can be explained primarily by heat capacity arguments. The freezing models used by SIMMER-II compared well with the complete set of experimental results.

(2) The stability of the dynamic dispersive or "boilup" regime is important because the rate and coherence of pool collapse determines reactivity ramp rates. A series of separate SIMMER-II calculations[9] was performed for comparison to other calculated results[10] based on more mechanistic and detailed modeling and to related experimental results. Variations in predicted boilup behavior due to dependencies on void fraction, interfield drag, noding variations, flow regime, and boundary conditions were assessed and found to be relatively small. The overall simulation of steady boilup by SIMMER-II is shown to be credible. SIMMER-II predictions of fuel crust growth strongly impact the duration of the boilup state but were not directly included; some results are included in Ref 8, however.

In summary, a mechanistic calculation of a complete transition-phase sequence for a large heterogeneous core LMFBR has been performed. Recriticalities occurred as the disruption progressed through a series of different subphases. The number and severity of recriticalities was directly related to the timing and scale of fuel removal and coherence of material motion. The energetics associated with transition-phase are not yet resolved but our understanding of the characteristics of disruption and the effects of uncertainties has been extended significantly.

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